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(54) Improved fatigue resistant eutectic solder.

(57) The fatigue resistance of lead-tin eutectic solder is increased by doping the solder with less than about 1.0 weight % of a dopant selected from cadmium, indium and antimony. The doped eutectic solder exhibits increased resistance to thermally or mechanically induced cyclic stress and strain. As a result, the fatigue resistance of the solder joint is increased. Combination of dopants, such as indium and cadmium, in combined amounts of less than 0.5 weight % are especially effective in increasing the fatigue resistance of the lead-tin eutectic solder.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to lead-tin eutectic solder. More particularly, the present invention relates to improving the fatigue resistance of lead-tin eutectic solder.

2. Description of Related Art:

Eutectic and near-eutectic lead-tin solder alloys are used to provide solder joints in a wide variety of electronic devices. In addition to providing electrical connections, the solder joint provides a vital mechanical link between electronic devices and connectors.

During operation, many electrical devices are subjected to vibration and continual changes in temperature. Many times, the coefficient of thermal expansion of the various materials at and around the solder joint are different. As a result, the continual changes in temperature cause the solder joint to be continually subjected to varying degrees of stress and strain. The solder joint may also undergo continual stress due to vibrations and other forces exerted against the joint.

It would be desirable to provide solder joints which are structurally strong and resist fatigue due to mechanical or thermal stress and strain. Such fatigue resistant solder would be especially well-suited for use in electronic equipment which is subjected to extreme thermal fluctuations and mechanical duress. Further, fatigue resistant solder would be desirable for use in electronic devices where a long service life is required.

SUMMARY OF THE INVENTION

In accordance with the present invention, an improved lead-tin eutectic solder is provided which is more resistant to fatigue and breakage than conventional lead-tin eutectic solder. The present invention is based upon the discovery that the addition of less than about 1.0 weight % of a dopant, such as cadmium, indium or antimony, increases the fatigue resistance of lead-tin eutectic solder.

As a feature of the present invention, it was discovered that optimum increases in fatigue resistance for the lead-tin eutectic solder was achieved by adding between about 0.1 and 0.8 weight % of the dopant. In addition, it was discovered that further increases in fatigue resistance can be achieved by adding a mixture of dopants, such as indium and cadmium. Large increases in fatigue resistance are obtained when the lead-tin eutectic is doped with about 0.2 weight % cadmium and about 0.2 weight % indium.

As another feature of the present invention, a method is disclosed wherein the doped lead-tin eutectic solder is used to bond two metal surfaces together. This method is especially well-suited for soldering the whole spectrum of electronic connectors together.

The present invention also provides a method of improving the fatigue resistance of a lead-tin solder joint by forming the solder joint from a lead-tin eutectic solder comprising the above-discussed dopant.

The improved lead-tin eutectic solder in accordance with the present invention is an improvement over existing lead-tin eutectic solder since it provides the same degree of electrical conductivity and connection as the conventional eutectic solder while at the same time providing increased resistance to fatigue and joint fracture in the solder joint.

The above-discussed and many other features and attendant advantages of the present invention will become better understood by reference to the following description of the preferred embodiments.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is based upon the discovery that lead-tin eutectic solder can be doped with small amounts of specific dopants in order to increase the resistance of the solder to fatigue and fracture caused by continual stress and strain at the solder joint. The lead-tin eutectic solder in accordance with the present invention includes conventional eutectic solder which is doped with less than about 1.0 weight % of the dopants cadmium, indium, or antimony or mixtures thereof.

The conventional lead-tin eutectic solder which is doped is the well-known and widely used eutectic solder material which contains 63 weight % tin and 37 weight % lead. The present invention is also applicable to near-eutectic lead-tin solders wherein the weight percent of tin and lead are about 3 weight % higher or lower than the 63/37 weight % eutectic mixture. As used herein the term "eutectic" is intended to include "near eutectic" compositions, unless otherwise specified.

The preferred amount of dopant added to the lead-tin eutectic solder is between about 0.1 and 0.8 weight % of dopant. The preferred dopants are cadmium and indium. The dopants may be added individually to the solder or they may be added in combination. Further, it was discovered that doping the lead-tin eutectic solder with both indium and cadmium at a total doping level of less than about 0.5 weight % provides even further increases in

fatigue resistance. When using a combination of dopants, the dopants may be added in equal or unequal amounts.

The dopants in accordance with the present invention are incorporated into the solder by any of the well known processes for doping lead-tin solders. Preferably, the dopants in granular form are added to the solder components in granular form and the solder pre-mix is heated to a sufficient temperature to form a liquid. The solder and dopants are maintained as a liquid for a sufficient time to insure uniform distribution of the dopants throughout the solder. Optionally, the granular dopant and the eutectic lead-tin solder may be melted to alloy the dopant. The doped solder may then be immediately used or solidified and stored for future use. Other procedures for doping the solder are possible provided that the dopants are uniformly distributed throughout the solder mixture.

The doped lead-tin solder in accordance with the present invention is used in the same manner as conventional lead-tin solder. The doped solder is well-suited for connecting wires, pins and other electrical interconnectors together. The preferred use for the doped solder is in providing joints which are subjected to continual thermal or mechanical stress and strain. However, the doped solder in accordance with the present invention may be used to replace lead-tin solder wherever a strong, solid and fatigue resistant solder joint is required.

Examples of practice are as follows.

Example 1

This example describes the formation and testing of a lead-tin eutectic solder containing 62.0 weight % tin and 37.0 weight % lead doped with 1 % cadmium. Doping was carried out by dry mixing a sufficient amount of cadmium solid with appropriate amounts of lead and tin granules to provide a 1.0 weight % cadmium level in the solder mix. The cadmium was then intimately alloyed in the molten eutectic solder at about 250°C for a period of at least 30 minutes in a controlled argon atmosphere to insure uniform distribution of the dopant. The cadmium doped eutectic solder displayed solder characteristics which are equivalent to the undoped eutectic solder. A dog-bone shaped tensile specimen was fabricated and mechanically tested using a testing machine obtained from Instron of Canton, Massachusetts, at room temperature. The cadmium doped specimen was loaded into the machine. A cyclic sawtooth stress waveform at 0.001 Hertz (Hz) was applied with a peak tensile stress at about 110% of the generic yield of the lead-tin solder at room temperature. The cadmium doped dog-bone specimen underwent 35 cycles prior to failure. An identical dog-bone shaped specimen was prepared from undoped lead-tin eutectic solder. The undoped eutectic solder lasted only two cycles prior to failure when subjected to the same tensile fatigue conditions.

Example 2

Lead-tin eutectic solder was doped with 0.8 weight % cadmium in the same manner as described in Example 1, except that the cadmium was alloyed in the molten eutectic whose surface was always fully covered by a layer of rosin mildly activated (RMA) solder flux to prevent oxidation. Alloying was performed at a temperature of about 250°C over a period of about 8 hours in a flowing nitrogen atmosphere. The addition of the 0.8 weight % cadmium dopant did not alter the soldering characteristics of the eutectic solder. Torsion test specimens made of cylindrical copper rods joined by the solder were prepared. These specimens were subjected to torsional (shear) fatigue testing of the solder joint with the Instron testing machine at room temperature. The cycling frequency was 0.01 Hz and the plastic strain range per cycle applied on the solder was approximately 10 %. The average cycles-to-failure for the 0.8% cadmium doped eutectic solder was 34. The average cycles-to-failure for an identical torsion test specimen of commercial lead-tin eutectic solder was 18.

Example 3

Lead-tin eutectic solder was doped with 0.4 weight % cadmium in the same manner as Example 2. Torsion test specimens were also prepared and subjected to testing in the same manner as Example 2. The specimens failed after an average of 32 cycles.

Example 4

Lead-tin eutectic solder was doped with 0.2 weight % cadmium following the procedure set forth in Example 2. Torsion test specimens were also prepared and subjected to testing under the same conditions as Example 2. The average cycles-to-failure for the specimens was 34.

Example 5

A doped lead-tin eutectic solder dog-bone specimen was prepared in the sam manner as Example 1 except that 1% indium was substituted for cadmium. The tensile testing conditions to establish cycles-to-failure were the same as in

Example 1. The indium doped sample lasted five cycles before failing.

Example 6

A doped lead-tin eutectic solder dog-bone specimen was prepared and tested in the same manner as Examples 1 and 5, except that antimony was used as the 1 % dopant. The cycles-to-failure for the antimony doped lead-tin eutectic solder was 4.

Example 7

Lead-tin eutectic solder was doped with 0.1 weight % cadmium and 0.1 weight % indium in the same manner as Examples 2, 3 and 4. The same torsional fatigue testing procedure as set forth in Example 2 was used. The average cycles-to-failure for this combined cadmium-indium doped eutectic solder was 53.

Example 8

Lead-tin eutectic solder was doped with 0.2 weight % cadmium and 0.2 weight % indium in the same manner as in Examples 2, 3, 4, and 7. The same torsional fatigue testing procedure as set forth in Example 2 was used. The average cycles-to-failure for the combined cadmium-indium doped eutectic solder was 120.

As is apparent from the above examples, doping of lead-tin eutectic solders in accordance with the present invention substantially increases the resistance of the solder to fatigue failure. Further, the combination of cadmium and indium to provide a total dopant level of less than 0.5 weight % provides an even further increase in fatigue resistance which is not obtained when a single dopant is used.

Having thus described exemplary embodiments of the present invention, it should be noted by those skilled in the art that the within disclosures are exemplary only and that various other alternatives, adaptations and modifications may be made within the scope of the present invention. Accordingly, the present invention is not limited to the specific embodiments as illustrated herein, but is only limited by the following claims.

Claims

1. In a lead-tin eutectic solder for use in soldering metal surfaces together, the improvement comprising doping said lead-tin eutectic solder with less than about 1.0 weight percent of a dopant selected from cadmium, indium, antimony, and mixtures thereof.

2. An improved lead-tin eutectic solder according to claim 1 wherein said lead-tin eutectic solder includes between about 0.1 and 0.8 weight percent of said dopant.

3. An improved lead-tin eutectic solder according to claim 1 wherein said lead-tin eutectic solder contains a mixture of cadmium and indium.

4. An improved lead-tin eutectic solder according to claim 3 wherein said lead-tin eutectic solder contains about 0.2 weight percent cadmium and about 0.2 weight percent indium.

5. An improved lead-tin eutectic solder according to claim 1 wherein said solder contains a mixture of indium and antimony.

6. In a method for soldering two metal surfaces together using lead-tin eutectic solder, wherein the improvement comprises doping said lead-tin eutectic solder with less than about 1.0 weight percent of a dopant selected from cadmium, indium, antimony, and mixtures thereof.

7. A method for improving the fatigue resistance of a lead-tin solder joint comprising forming said solder joint from a composition comprising:

   (a) lead-tin eutectic solder; and

   (b) less than about 1.0 weight percent of a dopant selected from of cadmium, indium, antimony, and mixtures thereof.

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EUROPEAN SEARCH REPORT

Application Number

EP 92 11 6286
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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-2 216 834 (TOYOTA MOTOR CORPORATION) 18 October 1989 * claims * ---	1,2,5-7	B23K35/26
X	GB-A-2 198 676 (MULTICORE SOLDERS LIMITED) 22 June 1988 * example 1 * ---	1,2,6,7	
X	EP-A-0 307 638 (DEMETRON ET AL) 22 March 1989 * column 2, line 45 * ---	1,2,6,7	
X	WELDING JOURNAL. vol. 54, no. 10, October 1975, MIAMI US pages 377S - 383S E.R.BANGS ET AL 'Effect of Low Frequency Thermal Cycling on the Crack Susceptibility of Soldered Joints' * tables 1,2 * ---	1,2,6,7	
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A	US-A-4 937 045 (R.M.SILVERMAN) 26 June 1990 ---		
A	PATENT ABSTRACTS OF JAPAN vol. 15, no. 164 (M-1106)24 April 1991 & JP-A-30 32 487 (TOYOTA MOTOR CORPORATION) 13 February 1991 * abstract * ---		
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 FEBRUARY 1993	MOLLET G.H.

CATEGORY OF CITED DOCUMENTS

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
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TECHNICAL FIELDS SEARCHED (Int. Cl.5)

The present search report has been drawn up for all claims

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THE HAGUE	25 FEBRUARY 1993	MOLLET G.H.

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